



Advanced Clean Coal

**California Energy Commission 2007
Integrated Energy Policy Report Committee
Workshop**

May 29, 2007

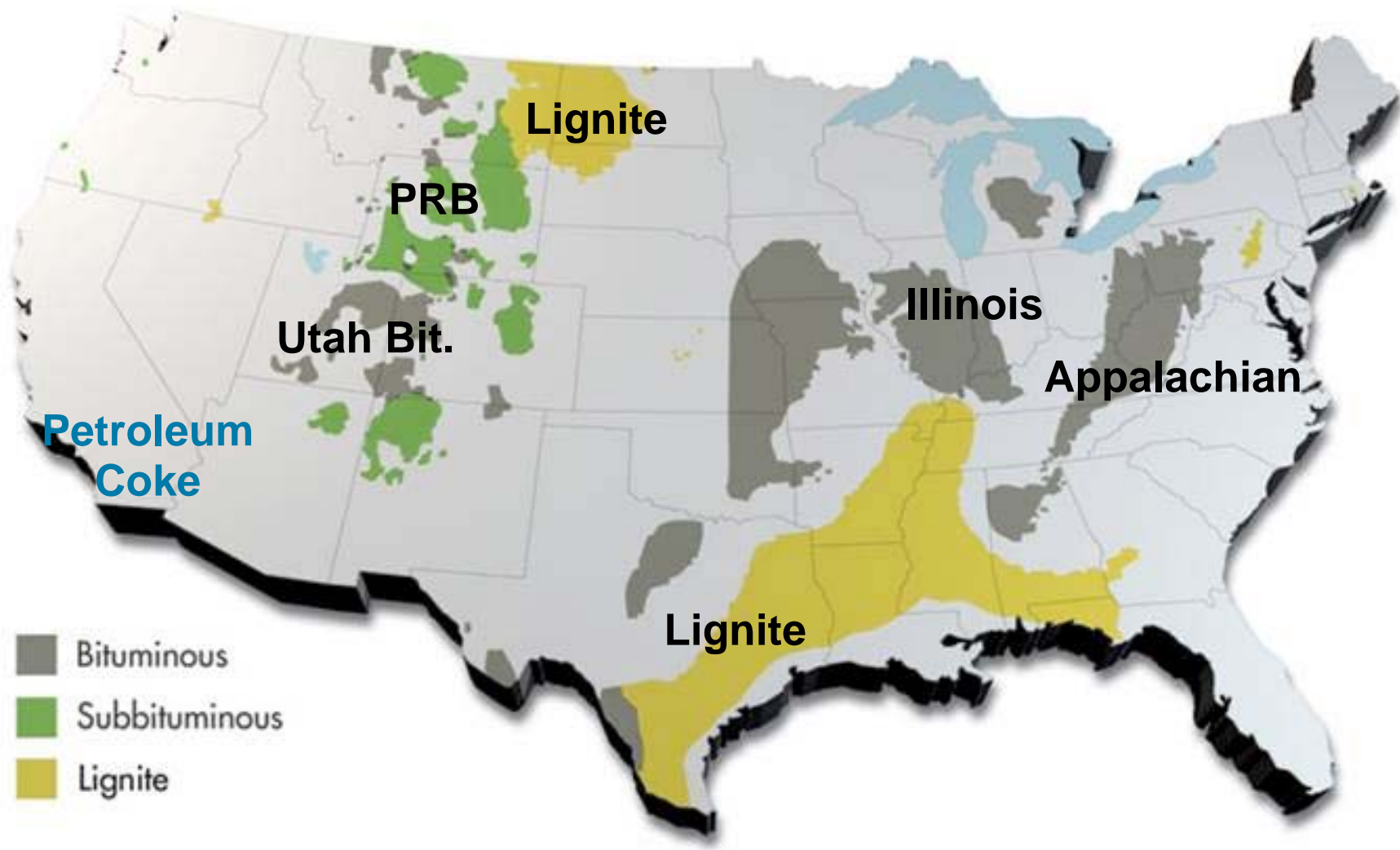
Sacramento, CA

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Outline of Presentation

- Technology Background without CCS
 - Status
 - Description
 - Emissions
- International perspective on clean coal
- Discussion

U.S. “Coal” Types and Basins

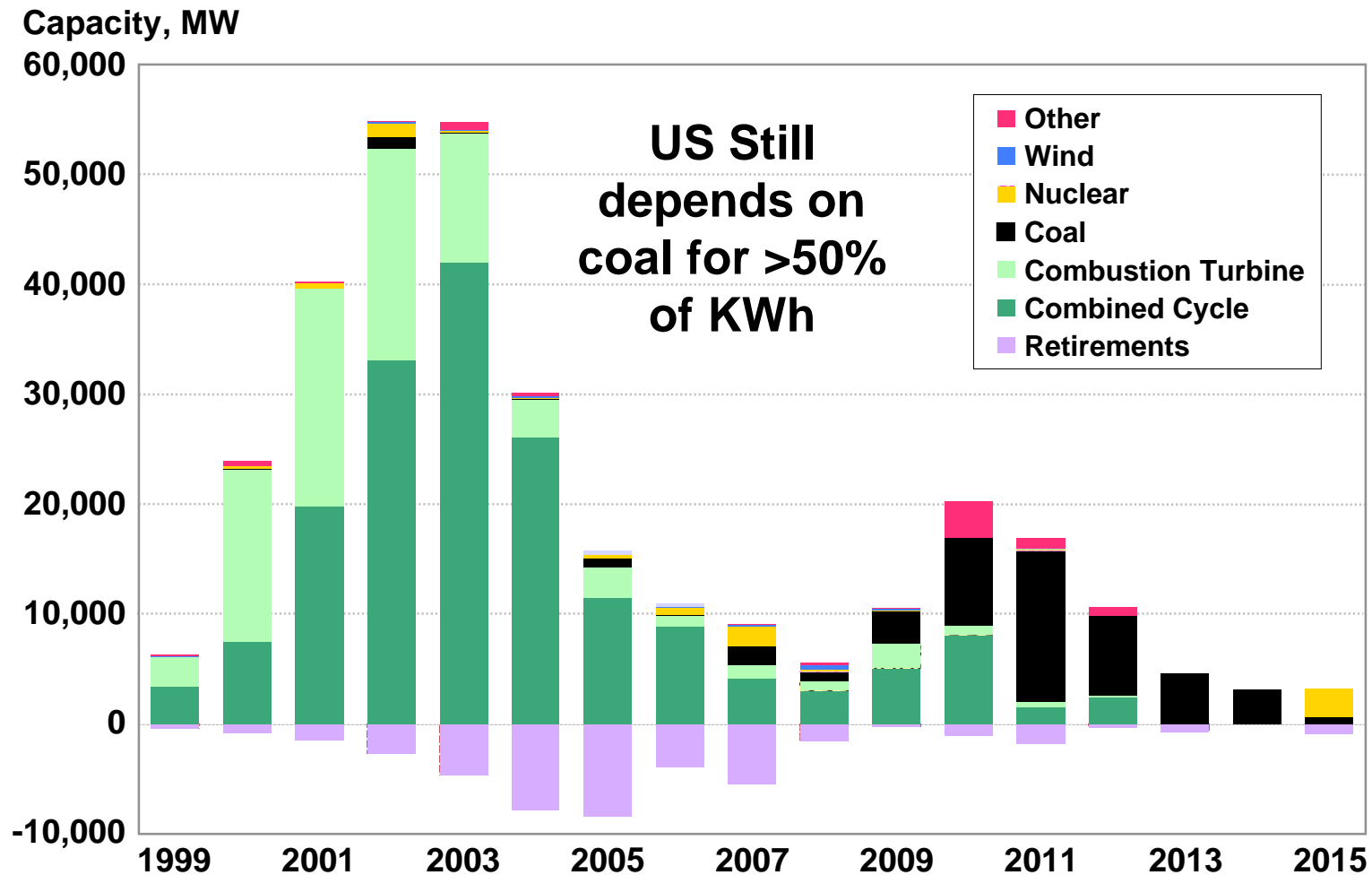


Key Messages

- A *Portfolio* is needed for the future – End-use Efficiency, Renewables, Nuclear power, Generation Efficiency and CO₂ Capture and Storage (CCS) all are important
- Efficiency improvements short term can reduce CO₂ emissions per kW 5% and by 20% over 20 years
- No coal technology is preferred for all coals, elevations, site conditions
- CoalFleet for Tomorrow is developing design guides for clean coal both with and without CCS

U.S. Capacity Additions – All Types

Evaluation of Announcements, 1999 to 2015, as of Fourth Qtr. 2006



"Other" includes biomass, solar, hydro, internal combustion, geothermal, pet coke or any other type with announcements available to investigator.

Capacity additions for each year prior to summer peak load season.

Source: Forthcoming "Power Plant Update" prepared for EPRI Program 67 by EVA.

How you “Clean” a Pulverized Coal Plant

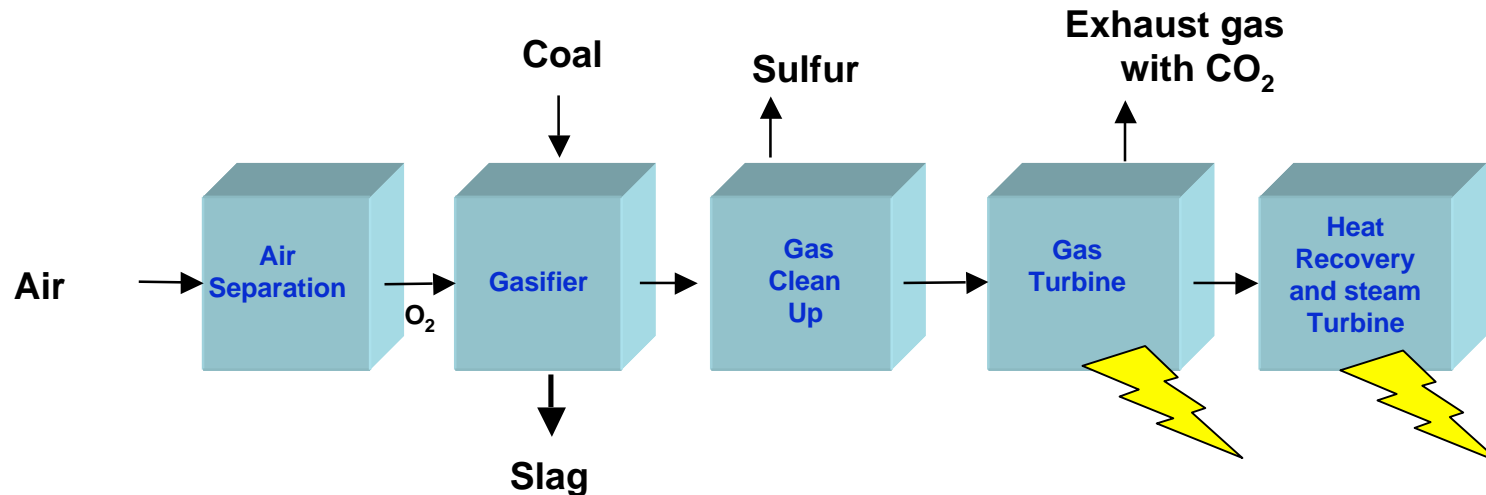


Fuel (low S) Burners (Low NO_x) Catalyst for NO_x Precipitator (Particulate) Scrubber (SO₂)

- **Fuel selection is critical for sulfur and other contaminants**
- **Burners on new units emit less NO_x via controlling fuel air mixing and temperature**
- **Billions being invested on selective catalytic reduction (SCR ...NO_x + NH₃ going to N₂ + H₂O) – very low NO_x possible combustion & SCR**
- **High efficiency (>99.5%) Electrostatic precipitators or fabric filters remove dust (flyash)**
- **Flue Gas Desulfurization (scrubbers) react limestone with SO₂ giving gypsum new designs 95%+ removal – 99% possible**

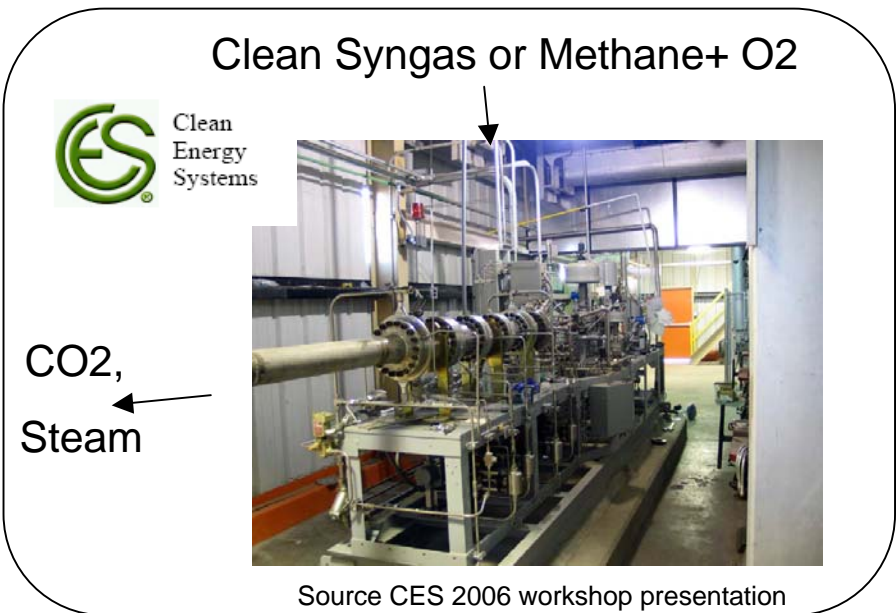
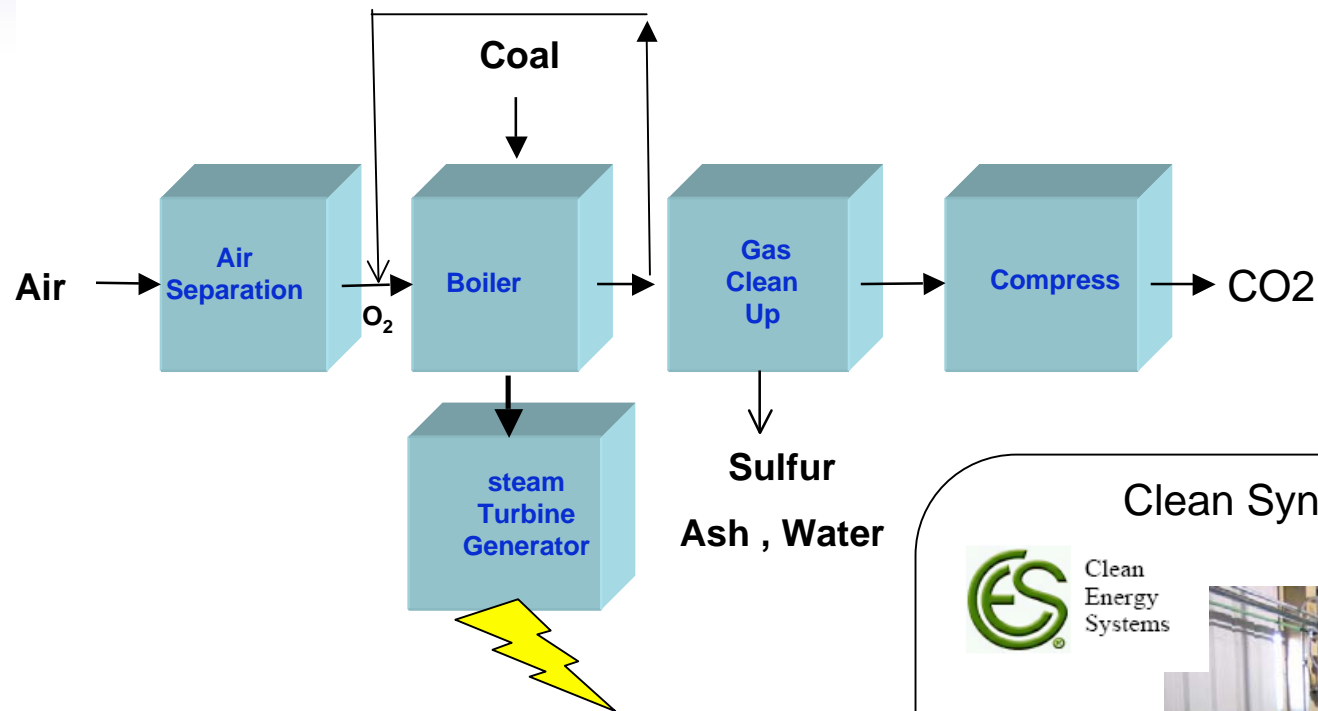
IGCC – what is it?

Integrated Gasification Combined Cycle



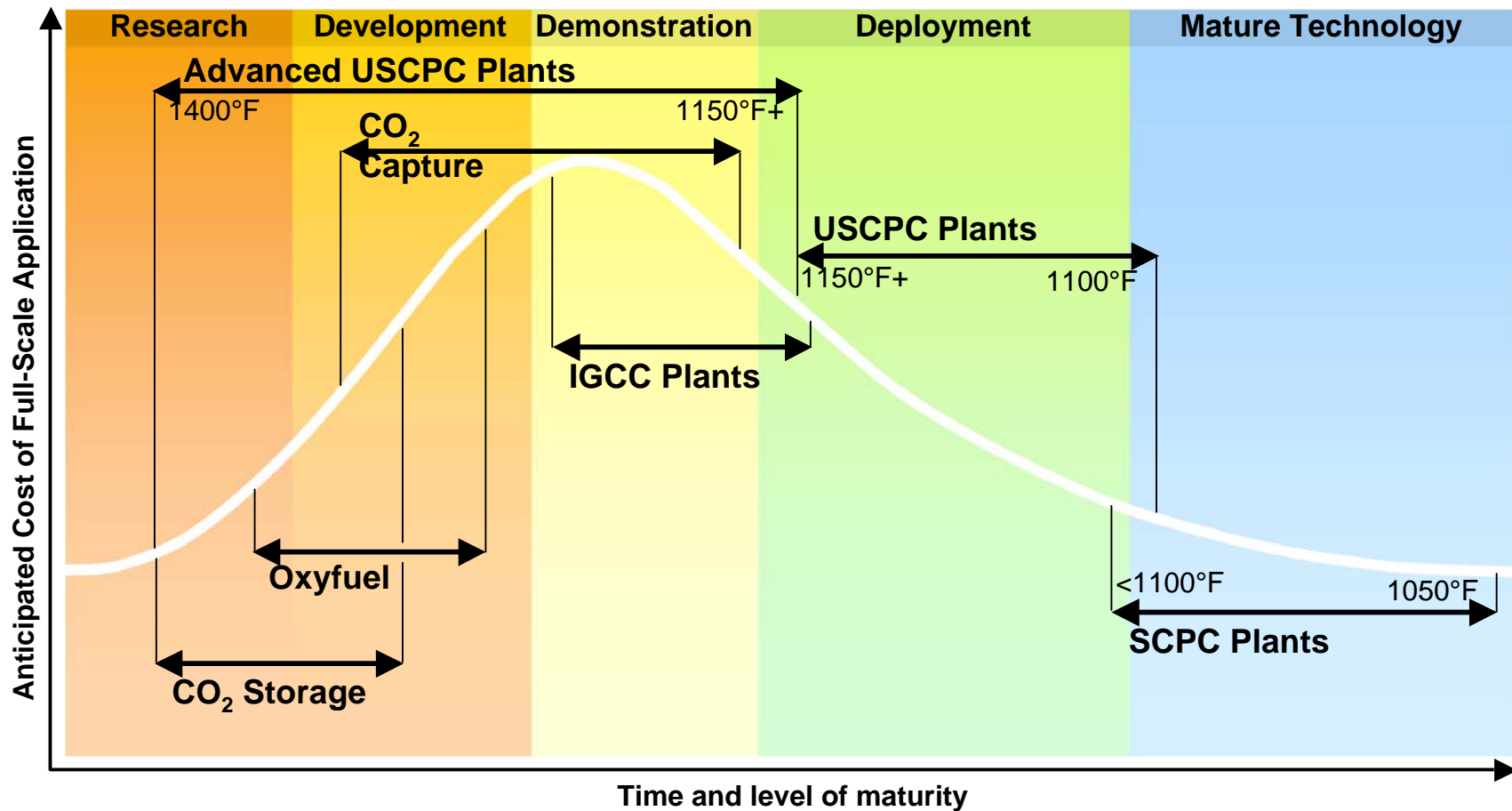
- Air is separated to oxygen, coal is converted to gas (CO and Hydrogen) and ash to a usable inert “slag”, the gas is cleaned and burned in a gas turbine/ generator, followed by heat recovery and a steam turbine/generator (the last two being the “combined cycle”)

Oxy-fuel/ Oxycoal “generic” as well as California’s own Clean Energy Systems



Source CES 2006 workshop presentation

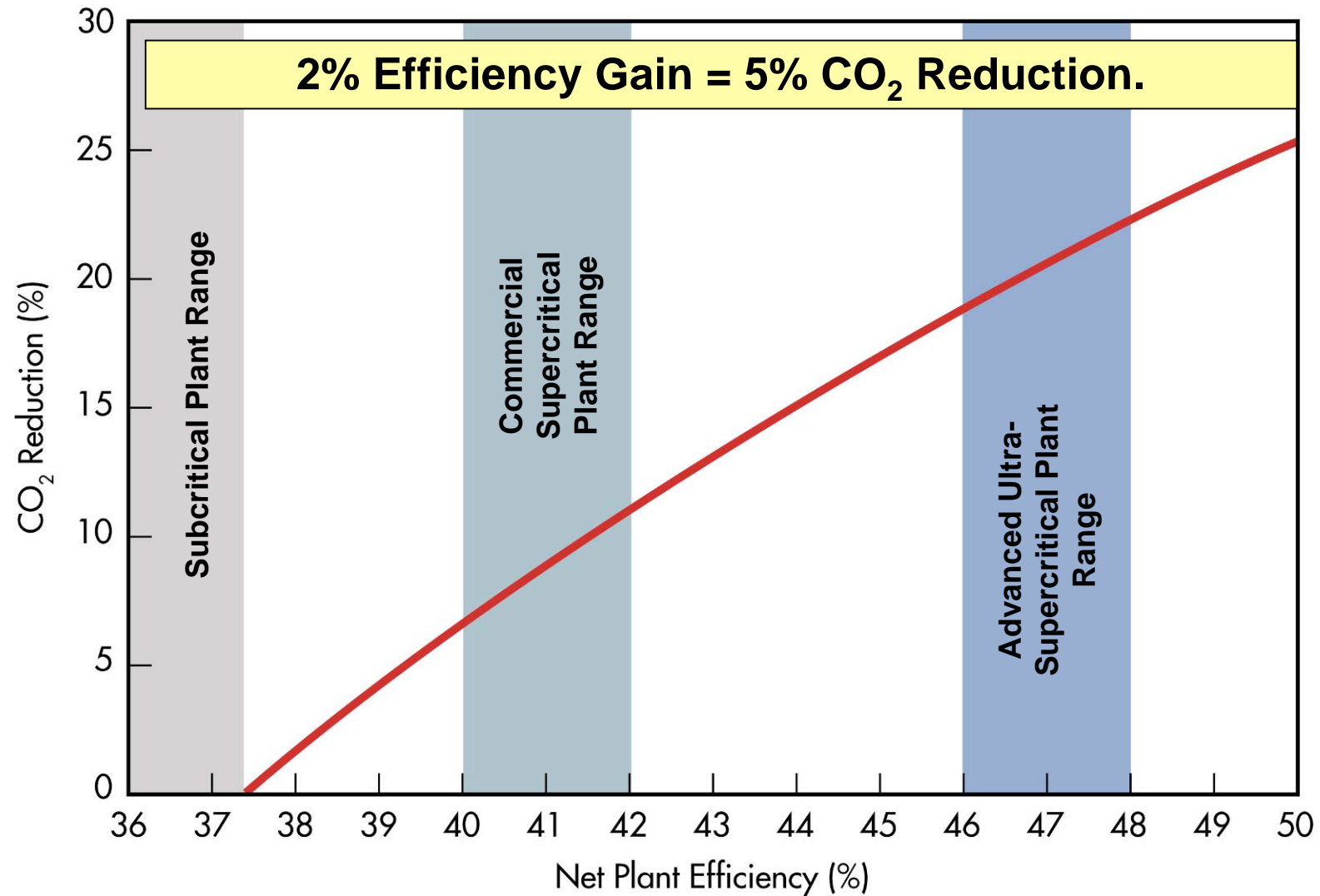
New Technology Deployment Curve for Coal



Not All Technologies at the Same Level of Maturity.

PC Plant Efficiency and CO₂ Reduction

20% improvement is possible



Existing Coal-Based IGCCs



Puertollano (Spain)



Wabash (Indiana)

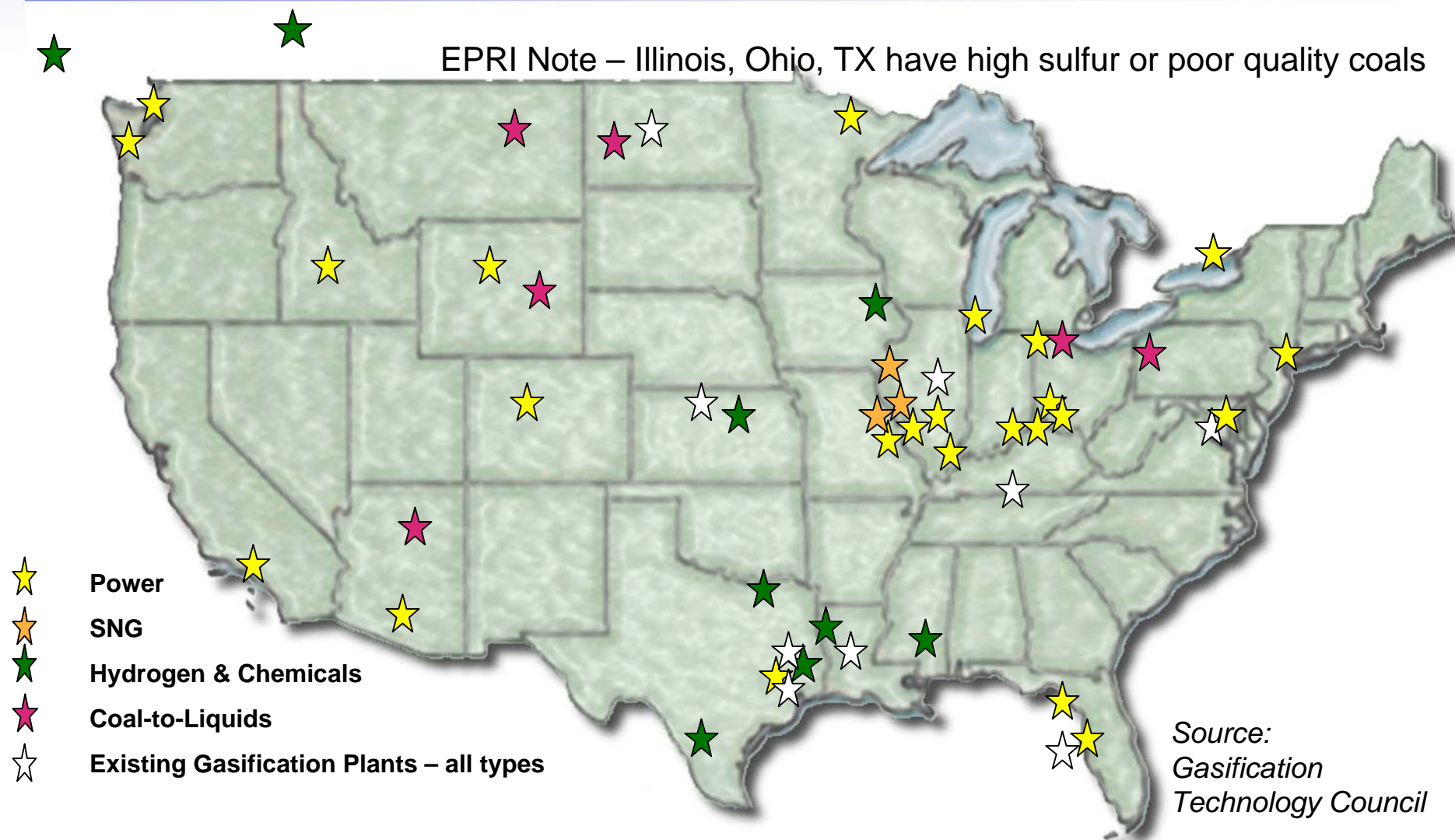


Polk (Florida)



Buggenum (Netherlands)

Publicly Announced Gasification Project Development



Coal Technology Options – w/o CO₂ Capture

(approximate data)

NSPS = New Source Performance Standards

PC = Pulverized Coal

SCPC = Supercritical PC

USPC = Ultra-Supercritical

IGCC = Integrated Gasification

NGCC = Natural Gas

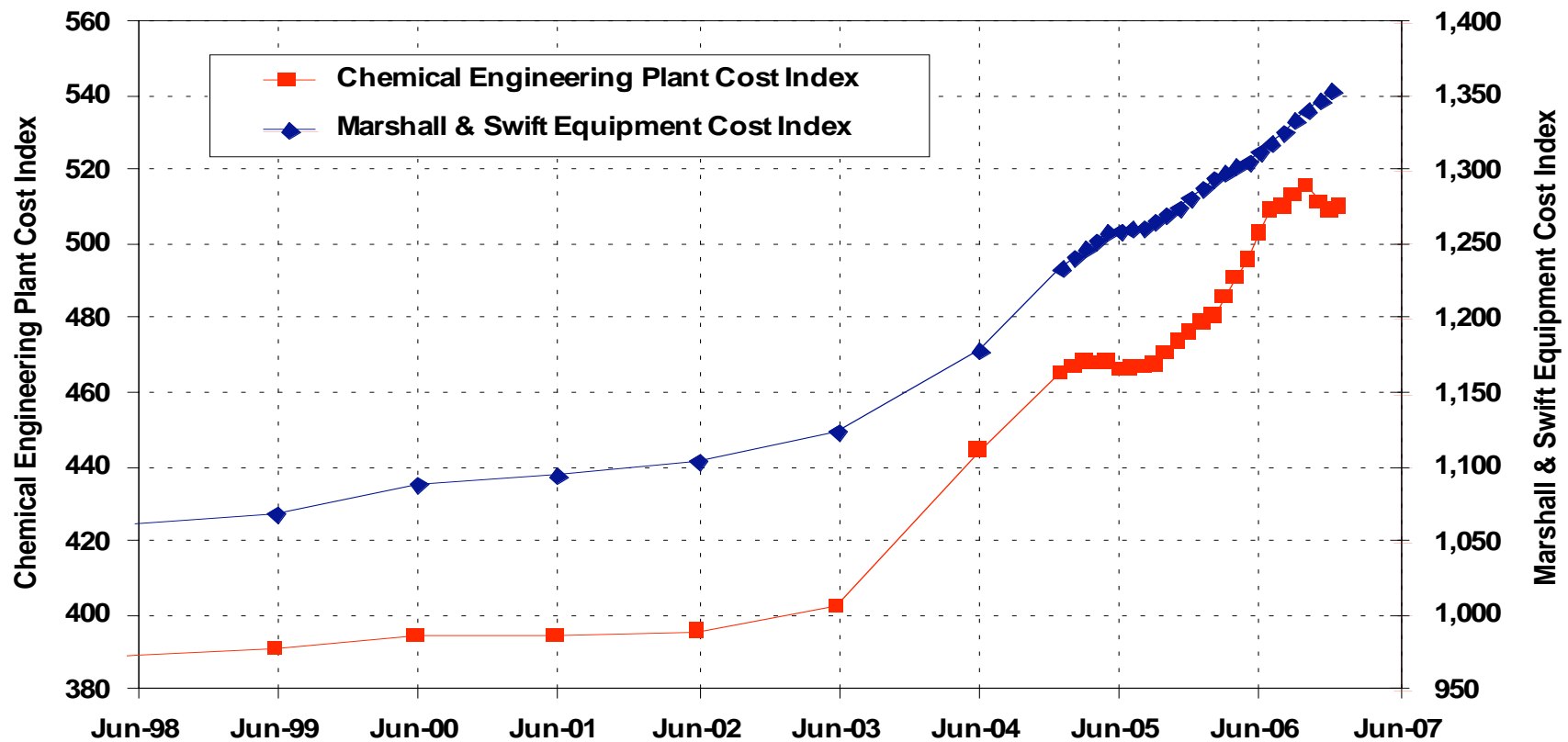
		NSPS 2006	PC Fleet Average	SCPC (1050°F Steam) w/ SCR	USPC (1100°F Steam) w/ SCR	IGCC (CoP E-Gas) w/ SCR	NGCC (GE 7FB) w/ SCR
	Efficiency <small>PRB Bit.</small> (HHV Basis)	--	33%	37% 38%	38% 39%	38% 39%	50%
Regulated	SO₂ lb/MW-hr	1.4	13	0.3 1.1	0.3 1.1	<0.1	nil
	NO_x lb/MW-hr	1.0	6	<0.3 <0.5	<0.3 <0.5	<0.2	<0.1
	Particulate lb/MW-hr	0.2	1	<0.2	<0.2	<0.1	nil
	Mercury % Reduction	--	~36%	80%	80%	90%	--
Non-Regulated	CO₂ lb/MW-hr	--	2,250	1,950 1,900	1,900 1,850	1,850 1,800	800
	Water Usage gal/MW-hr	--	1,200	1,100	1,000	750	600

Relative Emissions Profiles for PC and IGCC are Very Low.

Plant Construction Costs Escalating

Construction Cost Indices

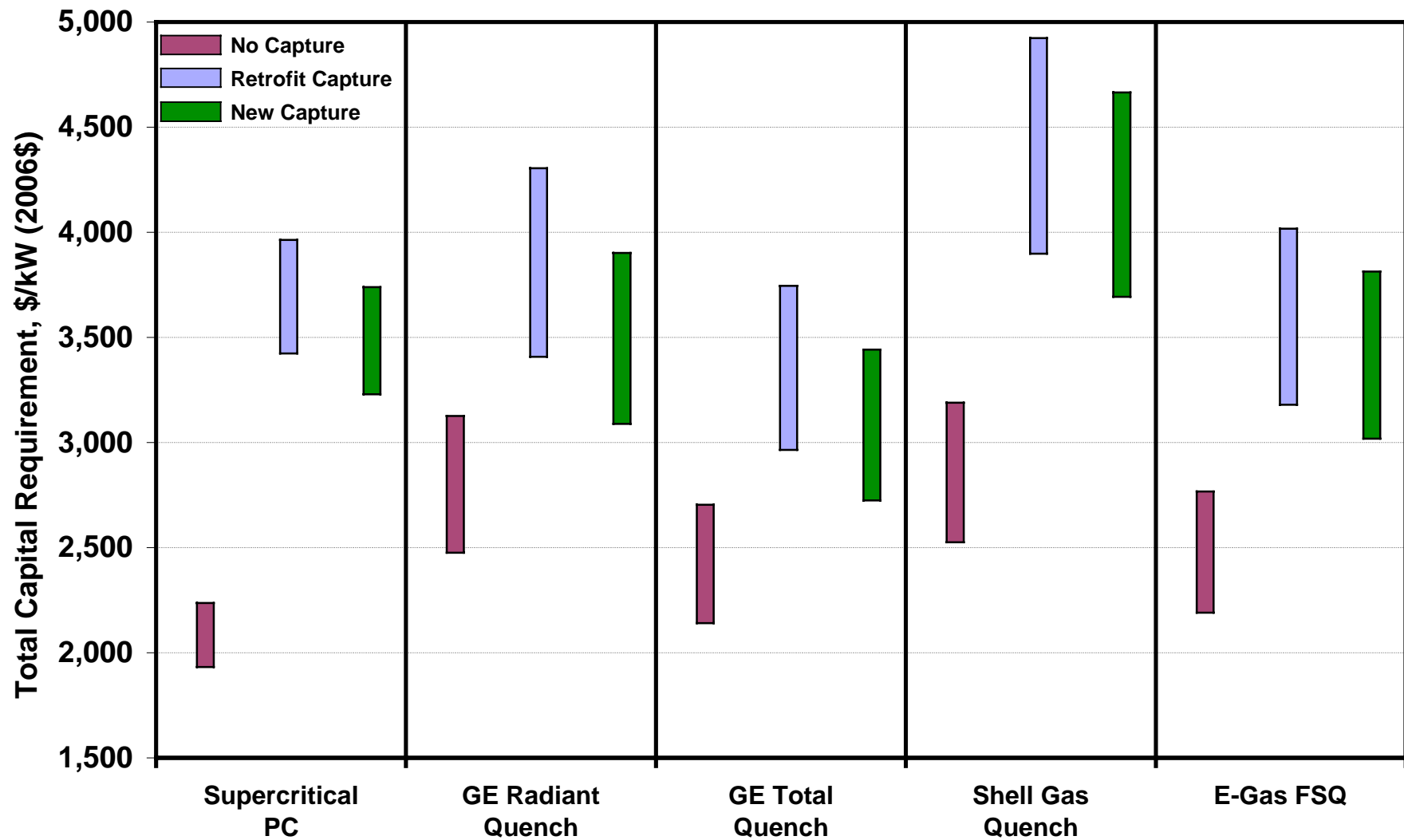
(Source: Chemical Engineering Magazine, March 2007)



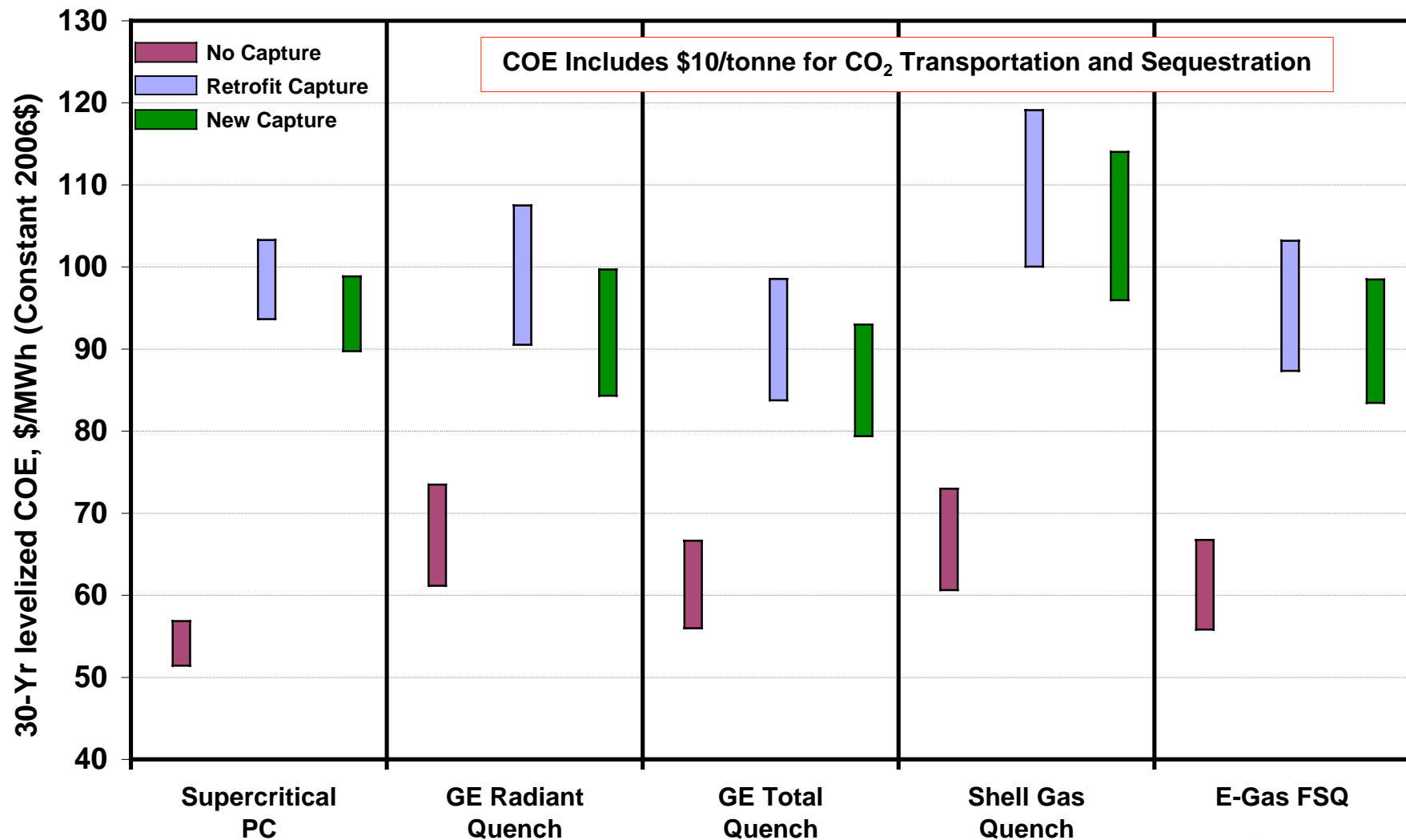
Capital Cost Estimates in Recent Press Announcements and Submissions to PUCs —All Costs Are Up!

Owner	Plant Name/ Location	Net MW	Technology/ Coal	Reported Capital \$ Million	Reported Capital \$/kW
AEP SWEPCO	Hempstead, AR	600	USC PC/PRB	1680	2800
AEP PSO/OGE	Sooner, OK	950	USC PC/PRB	1800	1895
AEP	Meigs County, OH	630	GE RQ IGCC/ Bituminous	1300 now ?	?
Duke Energy	Edwardsport, IN	630	GE RQ IGCC/ Bituminous	1985	3150
Duke Energy	Cliffside, NC	800	USC PC/Bit	1930	2413
NRG	Huntley, NY	620	IGCC/Bit, Pet Coke, PRB	1466	2365
Otter Tail/GRE	Big Stone, SD	620	USC PC/PRB	1500	2414
Southern Co	Kemper County, MS	600	KBR IGCC Lignite	1800	3000

EPRI PC and IGCC Capital Cost Estimates With and Without CO₂ Capture (Illinois #6 Coal) (All IGCC and CCS cases have +10% Contingency for FOAK)



EPRI PC and IGCC Cost of Electricity With and Without CO₂ Capture (Illinois #6 Coal) (All IGCC and CCS cases have +10% TPC Contingency for FOAK)



Coal Characteristics Drive Technology Selection

	IGCC w/ CCS	PC w/ CCS
Bituminous Coal	Usually Favored	
Sub-Bituminous Coal	Water use limits Lower elevation Lower moisture Lower ash	Higher elevation Higher moisture Higher ash Higher ambient temp.
Lignite Coal		Usually Favored

Nth Plant Economics

EPRI's CoalFleet for Tomorrow Program

- Build an industry-led program to accelerate the deployment of advanced coal-based power plants; members now span five continents
- Employ “learning by doing” approach; generalize actual deployment projects (50 & 60 Hz) to create design guides
- Augment ongoing RD&D to speed market introduction of improved designs and materials
- Deliver benefits of standardization to IGCC (integration gasification combined cycle), USC PC (ultra-supercritical pulverized-coal), and SC CFBC (supercritical circulating fluidized-bed combustion)
 - Lower costs, especially with CO₂ capture
 - High reliability
 - Near-zero SO_x, NO_x, and PM emissions
 - Shorter project schedule
 - Easier financing and insuring



CoalFleet for Tomorrow is an International Collaboration on Clean Coal including CO₂ Capture

- Participants from 5 continents , Asia, Australia, Europe, Africa, North America (2/3 of all coal fired in NA)
- Best design guides developed by industry for industry
- Power Producers, Suppliers, Rail, Coal, engineering firms, Governmental entities
- Many of the leading “early deployment” firms working with us to assure successful designs that meet the performance and operational goals
- New plants starting to look at designs for CO₂ capture and integration

CoalFleet Participants Span 5 Continents

>60% of U.S. Coal-Based Generation, Large European Generators, Major OEMs (50 & 60 Hz) and EPCs, CEC, U.S. DOE

- Alliant Energy Corp.
- Alstom Power
- Ameren Services Company
- American Electric Power
- Arkansas Electric Coop.
- Austin Energy
- Babcock & Wilcox Company
- Bechtel Corp.
- BP Alternative Energy International
- California Energy Commission
- ConocoPhillips Technology
- Consumers Energy
- CPS Energy
- CSX Transportation
- Dairyland Power Coop.
- Doosan Heavy Industries
- Duke Energy Corp.
- Dynegy
- EdF
- Edison International
- Edison Mission Energy
- ENEL
- Entergy
- E.ON UK
- E.ON US
- ESKOM
- Exelon Corp.
- FPL
- GE Energy (USA)
- Golden Valley Electrical Assoc.

CoalFleet Participants Span 5 Continents (cont'd)

- Great River Energy
- Hoosier Energy
- Integrys Energy Group (WPS)
- Jacksonville Electric Authority
- Kansas City Power & Light
- Kellogg Brown & Root (KBR)
- Lincoln Electric System
- Midwest Generation
- Minnesota Power
- Mitsubishi Heavy Industries (MHI)
- Nebraska Public Power District
- New York Power Authority
- Oglethorpe Power
- PacifiCorp
- PNM Resources
- Portland General Electric
- Pratt & Whitney Rocketdyne
- Richmond Power & Light
- Rio Tinto
- Salt River Project
- Siemens
- Southern California Edison
- Southern Company
- Stanwell Corporation
- TransCanada Pipelines Limited
- Tri-State G&T
- TVA
- TXU
- U.S. DOE (NETL)
- We Energies
- Wolverine Power
- Xcel Energy

What's Next – What's Needed for Coal

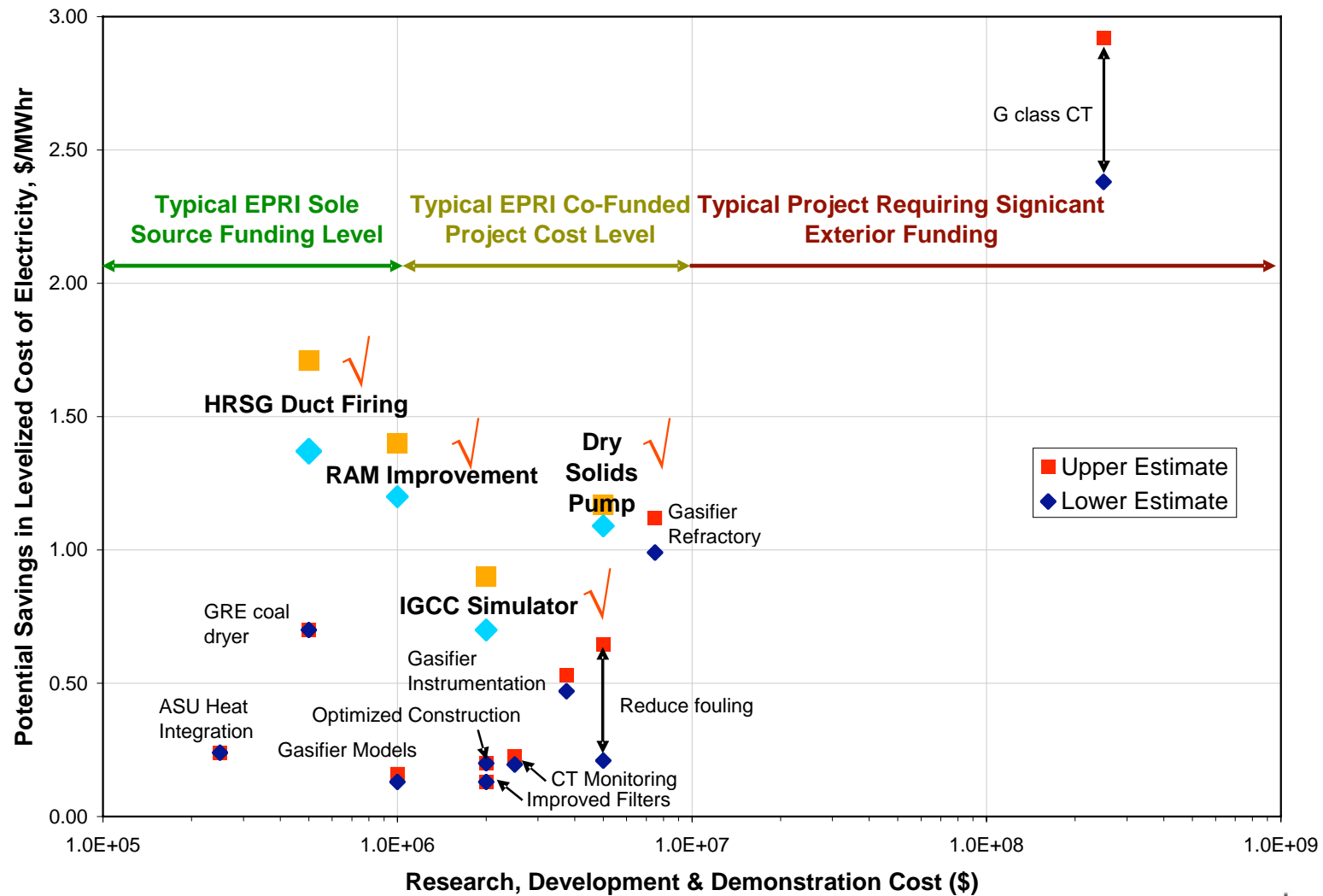
- Acceleration of the Industry efforts worldwide in addition to governmental efforts – new pilots, demonstrations, initiatives
- Cost reductions and efficiency improvements for the underlying technology
- Ways to deal with CO₂ (more later this afternoon)





Backup Slides

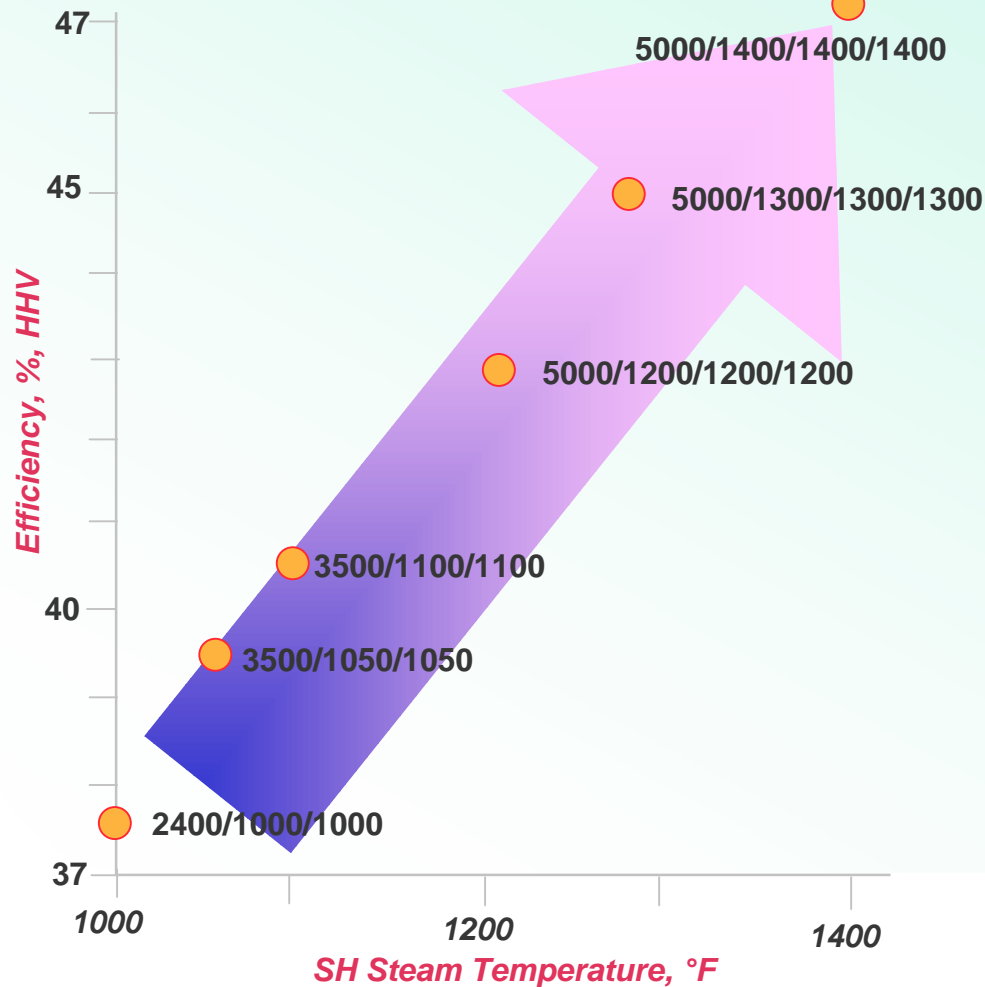
IGCC RD&D Plan: Near-Term Impacts and Cost



Status of Projects in Long-Term Plan

Fuel Cells	Adequate DOE funding at this point, private \$s needed in future for demonstration cost-share
Improved CO ₂ Separation	GE wants to propose 5-10 MW slipstream demo at an existing gasification facility (2008-2009)
ITM Oxygen Separation	Air Products plans a 150 tpd demo integrated with a combustion turbine – needs co-funding
Partial Water Quench of Dry-Feed Gasifiers	OEMs must take lead, but 3 rd party \$s may be needed for demos
Liquid CO ₂ – Coal Slurry	EPRI initiating \$90K project to better define potential value
Stamet pump with un-dried coal	Await successful demo on dried coal before going further
Warm Gas Clean-up	TECO has expressed interest in hosting a demo, but needs more analysis of economics
H Class CT	Await successful demos on natural gas
Supercritical Steam Cycle	Siemens has proposed SC steam cycle for new H class combined cycle

Ultrasupercritical PC Plants



- **European and Japanese USC PC Experience Base**

- 600°C (1112°F) high availability, good load following
- Baseline S-O-A for a new coal-fired plant

- **In Development:**

- European Advanced 700°C (1292°F) PC plant *stalled?*
- *DOE EIO/ EPRI 760°C (1400°F) boiler materials program*

Coal IGCC and CCS Example Projects in AP-6 Counties



- **Eagle** – Japan based 150 tpd 2 stage entrained flow oxygen blown
- **FutureGen** – U.S. based program for 275 MW IGCC oxygen blown with H₂ production plus CO₂ Capture and Storage (CCS) with international financial support
- **Greengem** – China based program for 250 MW+ IGCC plus CCS
- **Nakoso project** – Japan based IGCC 250 MW Air Blown
- **ZeroGen** – Australia based program ~100 MW IGCC plus CCS
- **CoalFleet for Tomorrow®** - U.S. based international collaborative project to develop design guidelines for IGCC plus the option of CCS and accelerate deployment of advanced coal

E.ON UK comments on CCS projects in Europe

Project	Location	Scale, MW	Timing	Comments
BP/SSE	UK, Peterhead/Miller	350 Cancelled	2014	NGCC + CCS, EOR
Vattenfall	Germany, Pilot Germany, Commercial	30 ???	2008 2020	Oxyfuel, no CCS Lignite
Shell/Statoil	Norway	850	2011	NGCC + CCS, EOR
RWE Power	Germany	450	2014	IGCC + CCS
Progressive Energy	UK, Teeside	800	2011	IGCC + CCS, EOR Coal, petcoke
PowerFuels	UK, Hatfield	900	Post 2012	IGCC + CCS
E.ON UK	UK, Killingholme	450	2012	IGCC + CCS
RWE nPower	UK, Tilbury	1000	2016	S/C with CCS
SSE	UK, Ferrybridge	500	?	S/C Retrofit